A Mission Planning Toolkit (MPT) for Coordination and Control of Multiple Autonomous Vehicles

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LONG TERM GOALS

The Autonomous Ocean Sampling Network (AOSN II) program, as currently envisioned, is an initial step to implement adaptive sampling utilizing multiple sensing platforms. A key aspect of this program is the ability for many heterogeneous assets to communicate data and information among and between each other as well as with geographically dispersed users. The communication infrastructure necessary to allow this to happen is complex. It implies seamless communications from the sea bottom through the water column to surface and air borne craft. The Mission Planning Toolkit for Coordination and Control of Multiple Autonomous Vehicles supports the AOSN efforts.

The communication infrastructure to allow this to happen can be thought of as having three components: 1.) an effective method of communicating from one vehicle or node to another (a link), 2.) a method of interconnecting the individual vehicles or communication nodes (a network), and 3.) a common understanding of the information, data and commands to be passed through the communication infrastructure (a common vocabulary/language). This is critically important if the autonomous systems are to eventually accomplish a defined task with only minimal intervention of a human operator/s.

The long-term goal of this effort is to provide a means for controlling a fleet of AUVs while they accomplish a cooperative mission. Specifically this implies a user interface and a mission-programming environment to allow a user to configure the fleet of vehicles to accomplish a desired task. In concert with this development of a user interface is a development effort to establish a Common Control Language (CCL) that will provide a standard command language for heterogeneous AUVs.

OBJECTIVES

There are two primary objectives being addressed in this program. The first is to investigate the issues associated with a mission-programming environment required to control a fleet of AUVs. This activity is encompassed in the development of the Autonomous Systems Monitoring and Control (ASMAC) – Mission Programming Toolkit (MPT). The ASMAC-MPT effort has progressed to a point where a simulation has been undertaken that simulates three solar powered AUVs alternately positioning themselves in three defined locations. The second objective is to identify a Common Control Language (CCL) that can be used among heterogeneous AUVS

APPROACH

When cooperation of multiple AUVs is to be accomplished, there exists a need to communicate with multiple vehicles yet there also exists an inherent limitation to the communication bandwidth available. This demands that the communication be undertaken utilizing high level (abstract) commands and information. This abstract information must then be decomposed onboard the vehicle. This places demands on the computational capability within the AUVs but ameliorates, to some degree, the limited communication bandwidth problems. ASMAC-MPT's chief purpose will be to provide a user with a tool for experimenting with different operational strategies for remotely controlling multiple agents in the CADCON (Cooperative AUV Development Concept) context [Reference 1]. It will provide users with a means to gain experience with the complex endeavor of controlling multiple entities in order to achieve complex goals. There are three main aspects to an ASMAC session. First, the user will use it to set up a particular operational scenario, and then initiate its start. Second, ASMAC will provide the user with the means to monitor the mission as its agents go about their business. Third, ASMAC will provide mechanisms for analyzing the mission scenario once it has been completed. ASMAC will only provide the mechanisms to assist the user in controlling multiple vehicles and intelligent platforms; what is learned from using ASMAC will provide some of the insights necessary to implement higher-level autonomous control within an AOSN.

ASMAC Structure: The planning / monitoring / modifying process is seen as utilizing three components: 1) a User Interface, 2) a data table and command generator DTCG and, 3) the actual SAUV systems or AUVsim clients. The User Interface and DTCG make up the ASMAC client, which communicates to the SAUVS or AUVsim clients via the CADCON infrastructure.

ASMAC User Interface: The User Interface allows the user to configure, monitor and modify the operation of the SAUV systems.
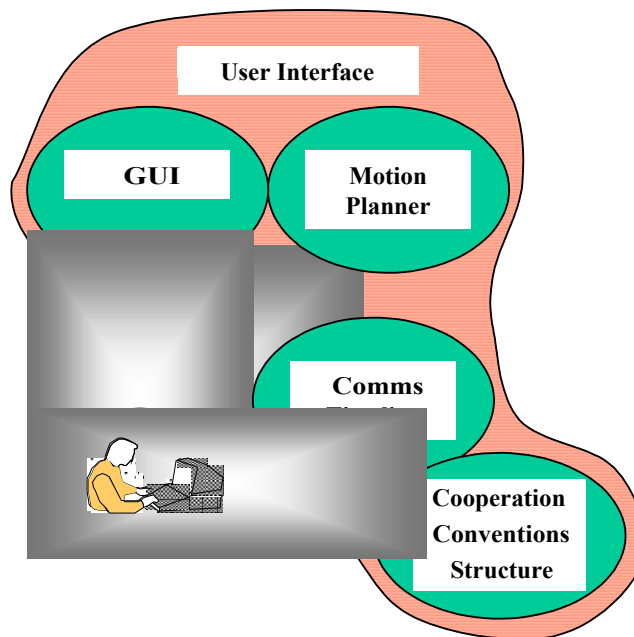

Figure 1. ASMAC User Interface

The **Cooperation Conventions Structure** consists of the cooperative behaviors that allow an individual SAUV to function between communication periods and to manage time, space, sequence, and energy interactions as appropriate to mission goals

The **Communications Timeline** module details the time that communications can be undertaken among and between all of the SAUVs and the user. The motion planner predicts when communications can take place based on predicted distances between the individual SAUVs as well as understanding when the user can communicate to the SAUVs on the surface based on the type of comms link available (RF, Cellular, Satellite). The module also describes the potential of relay communication paths as well as the timing of store and forward type of communications. The module acquires data of when communications actually occurred between various agents and the user.

The **Motion Planner** allows the user to plan paths and the various evolutions required to accomplish the mission goals. In that planning process, data is generated to correspond to each SAUV's status while accomplishing the mission. It time tags the predicted data.

The **Graphical User Interface (GUI)** displays the plans that have been made to the user. The user can also enter data via the GUI as well as entering data to the individual modules in form of entering text to instantiate various parameter registers

ASMAC Data Table / Command Generator: These modules are part of the User Interface. They interface with the SAUV systems or AUVsim clients via the CADCON infrastructure.
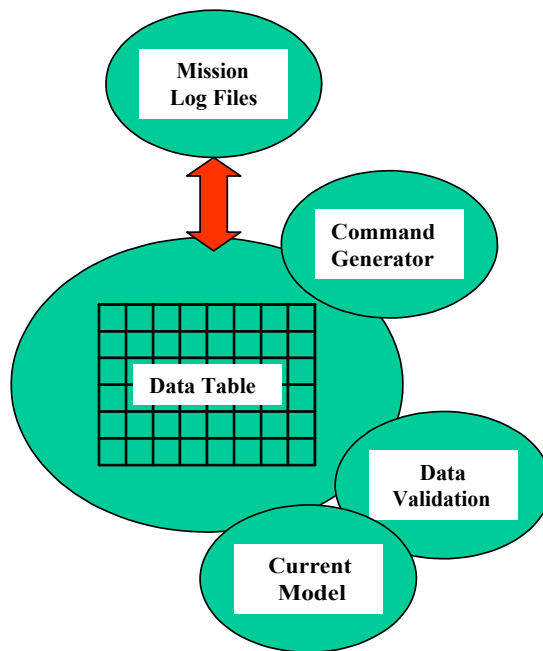

Figure 2. ASMAC Data Tables and Command Generator (DTCG)

The **Data Table** consists of three data arrays. All of these arrays have a duplicate structure. One of the arrays is used by the command generator to build commands that will be sent to the SAUVS or AUVsim clients. A second array is used by the user to plan or re-plan the mission. This process can go on without affecting the array being used by the command generator. In this way the user does not inadvertently affect the current plan in place. The third array is being used as a repository of data acquired over time from the SAUVs or AUVsim clients. This data that has been validated by the data validation module.
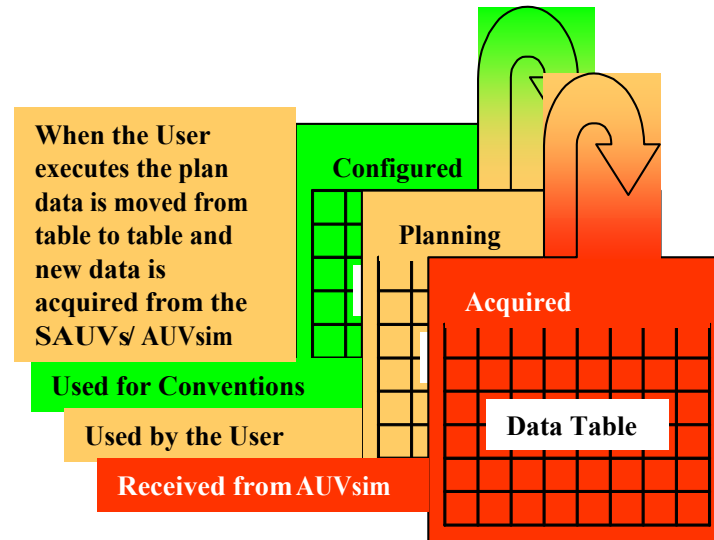

Figure 3. ASMAC Data Tables

When a user chooses to begin a re-planning process, the acquired data (array 3) is shifted to the planning array (array 2). It replaces existing data and prepares the second array for the planning process. The user may then adjust the plan in place based on the most current data. Once the planning process is completed, the user executes the new plan. At this point the data and information in array 2 is shifted into array 1 and then used as the information that will drive the command generator module.

The **Mission Log Files** are updated as the data arrays change and are stored for future analysis as deemed necessary.

The **Command Generator** is activated by the user once the user is satisfied with the plan he/she has configured. The User executes the plan and the Command Generator then proceeds to establish the commands necessary to implement the user's plan. The commands are then sent to the various SAUVs or the AUVsim clients. This process may be implemented by direct communication, by relay or by a store and forward process. The command generator module updates the data used by the communications timeline module in the user interface thereby allowing the user to understand what is happening. Once the commands are sent, the command generator will receive acknowledgments and update the communications timeline module with that information.

The **Current Model** module is tasked to maintain and update its understanding of currents in the operational area. This model utilizes information from a-priori knowledge as well as acquired knowledge obtained from the status reports being acquired from the various SAUVs. It is the function

of this module to provide local current data and making that information available to the motion planner.

The **Data Validation** module is tasked to validate the acquired information as it is received from the various SAUVs or AUVsim clients. This module contains procedures for making sure that acquired data does not exceed values that are obviously impossible or violate other constraints that are programmed by the user prior to execution of the proposed mission. Once validate the data is move to the appropriate locations in the data table. This module also time tags the incoming data.

WORK COMPLETED

Implementation of the design concept has progressed to a point where an ASMAC-MPT simulation has been undertaken that simulates three solar powered AUVs alternately positioning themselves in three defined locations. This is a critical piece of the overall ASMAC-MPT capability. It has identified a number of problems that must be addressed and given insight as to the complexity of the overall problem. It has clearly validated the design concept established for an ASMAC-MPT system.

IMPACT/APPLICATIONS

Future multiple AUV missions will require an ASMAC-like capability. As a user begins to control more than a single AUV, the burden of doing so increases dramatically as the number of autonomous systems increases. The ongoing work will have direct impact on these future systems.

REFERENCES

Chappell, S.G., Komerska, R., 2001, "An Environment for High Level Multiple AUV Simulation and Communication", Proceedings of Underwater Invention, New Orleans, LA, Feb/Mar 2001.